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PERFORMANCE ANALYSES OF SOLAR STILL COUPLED WITH VACUUM TUBES

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ABSTRACT

Drinking water is necessary to our daily living and for sustainable life. The access of clean water is one of the main issues, especially in most of Asian and African countries. There are necessities to encourage the renewable technologies, such as solar distillation, that is abundant and environmental friendly. The increasing demand on renewable systems usage worldwide and techniques based on effective capturing of solar energy will creates ustainability. Solar stills are depending on distillation process that utilizes solar energy. Solar stills generate pure clean water from brackish water. They are suitable for domestic users in rural regions due to easy operation and maintenance. Their dependence on solar radiation and low yield are behind their wide spread usage. This study is testing the efficiency of the solar still as clean-water supplier. Hence, a single slope solar-still has been tested for its overall yield with or without coupling with solar vacuum tubes under Jordanian climatic conditions. The results of the experimental tests have been investigated in this study. The main contribution of this study pertains to the analyses of the solar still coupled with vacuum tubes and singles lopeal one both under Jordanian climate conditions. The results of the experimental study showed that the coupling of the vacuum tubes with single solar still has increased the yield by 50% than an uncoupled system.

KEYWORDS: Solar Energy, Solar Still, Renewable Resources & Clean Water

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Original Article

1. INTRODUCTION

Fresh water and solar radiation are the main components of enhancing life of the poor nations. Clean water is essential for human living. Clean water demand is dramatically increasing due to expansion of industries, high planting activities, high standards of living and increase in population.[1,2] Around 4% of global water is drinkable and such a quantity is unevenly distributed between human beings globally. There is shortage of clean water in many regions around the world.[2] Investigations showed that every 0.6% of those who drink unclean water die from diseases caused by the water contamination in brackish swamps.[2] There are many methods of having clean water from saline water.[2,3] The use of solar stills for the distillation of brackish water is viable and it can use renewable energy, especially in hot climates. Previous studies[1,2,3,4,5,6] showed that solar distillation can purify the contaminated water. This is as a result of the photogenic inactivation of the microbes suspended in brackish water.[2,3] Single slope still is so common nowadays[1,2,3]. The solar stills types are symmetrical still, symmetrical double sloped still, V-trough type solar still, inflated cover and step base. The still yield of solar stills affected by many factors like climate parameters, such as solar Irradiance, ambient surrounding, clouds. [1-9] Many conditions like thermo physical, still orientation, tilt angle of glass, basin type, vapor closure, operational parameters (i.e., water depth, salinity and water temperature).[1,2,3]

2. LITERATURE REVIEW

Many design variations have been tested. The yield of the distillation can vary with the solar window, global position, ambient conditions and solar still type. Al Hayek and Badran,[1] Badran and Al Tahaineh[5] and Badran and Abu Khader[6] investigated different parameters, such as depth, salinity, dye, solar insulation AND wind speed.

Al-Hayek and Badran[1] found that the yield of asymmetrical greenhouse type was 20% higher than that of symmetric greenhouse type.

Hansen *et al.*[7] showed in their experimental investigation using wicks that the productivity was 4.28 liters per day.

Sathyamurthy *et al.* [8] carried out tests using a semicircular absorber still. Their results indicated that yield increased by 16.6%.

Durkaieswaran and Murugavel[9] showed in their reviewed paper that effectivity of the still increased by 32–47%, and the yield of 5 liters/m^2 per day.

Also, various types of stills were built since long time, but the most economical solar still with good yield is a challenge. Some researchers investigated the increase of the temperature of the inlet water to the basin,[5] enhancing condenser temperature,[10] and use of different heat storage material.[11] Raja seenivasan *et al.*[12] studied the effect of using flat plate collector with still. They had 60% increase in productivity than normal solar still. Appadurai *et al.*[13] manufactured a solar distiller. Their still was attached with fins and connected to a solar pond. They found that their productivity increased by 50%. Kumar *et al.*[14] observed agitation by extracting the vapor from still to external condenser. Their results show that their still enhanced the yield by 39.49%.

The present research attempted to analyze the efficiency of a solar still coupled with vacuum tubes under prevailing weather condition in the Faculty of Engineering Technology located in Marka, Amman.

3. SOLAR STILL PRINCIPLES

Sun rays passing through the glass cover is absorbed by water inside the solar still so that basin water temperature is elevated. This will lead to more evaporation. Then, basin water change phases from evaporation to condensation on the glass. The condensation slid down to the trough, and then collected inside a jug, as shown in figure 1.

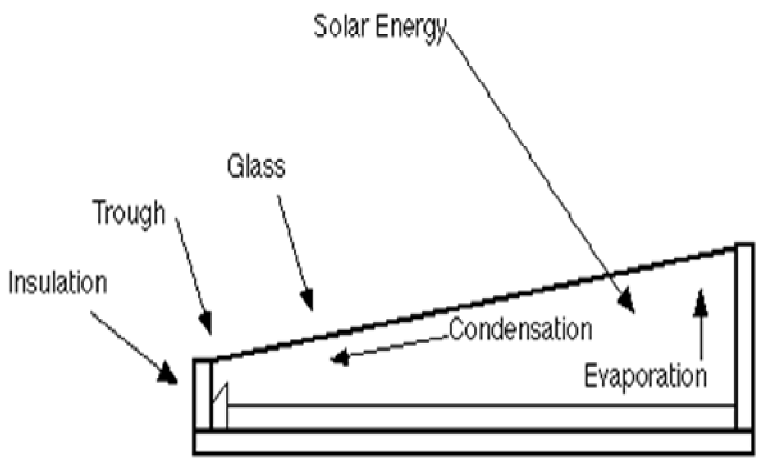

Figure 1: Solar Still Process.

4. SOLAR STILL SETUP

In the present study, the designed still consists of the following: the basin dimension is 1 meter square, manufactured of steel sheet having 1.5 mm thickness and base sprayed by black color to absorb solar radiation. The basin and the still sides were of polystyrene of 5 cm thickness. The purpose of the trough is to collect the slipping condensation from the glass cover. All parameters are measured hourly. The solar still components were installed on the roof of our Mechanical Engineering Department at FET, as shown in figures 2–4.

Figure 2: Overall Solar Still and Vacuum Tube Systems.

Figure 3: Single Slope Solar Still.

Figure 4: Data Acquisition, Computerized Equipments and Wind Anemometer.

5. RESULTS AND DISCUSSIONS

Experimental work data are collected at different days, where the solar irradiance outside temperatures and wind speed are considered as the main factors under consideration. It can be seen from figures 5 and 9 that with the increase in wind speed (figures 8 and 12) and the increase of ambient temperature (figures 5 and 9) the distillate output (figures 7 and 11) will be higher due to the increase in the basin's heat capacitance of the still and the increase in heat gain due to the temperature differences between the steam inside the still and the glass temperatures, in both experiments. Basin water temperature gained at higher ambient temperature and higher wind velocity ensures higher productivity, as evident from figures 9 and 5, where the productivity increases by 12% due to the combined effects. Also, the increase of the wind speed on the glass surface, which acts as a cooling process increases the condensation phase of the solar still that can enhance significantly the productivity of the distiller.

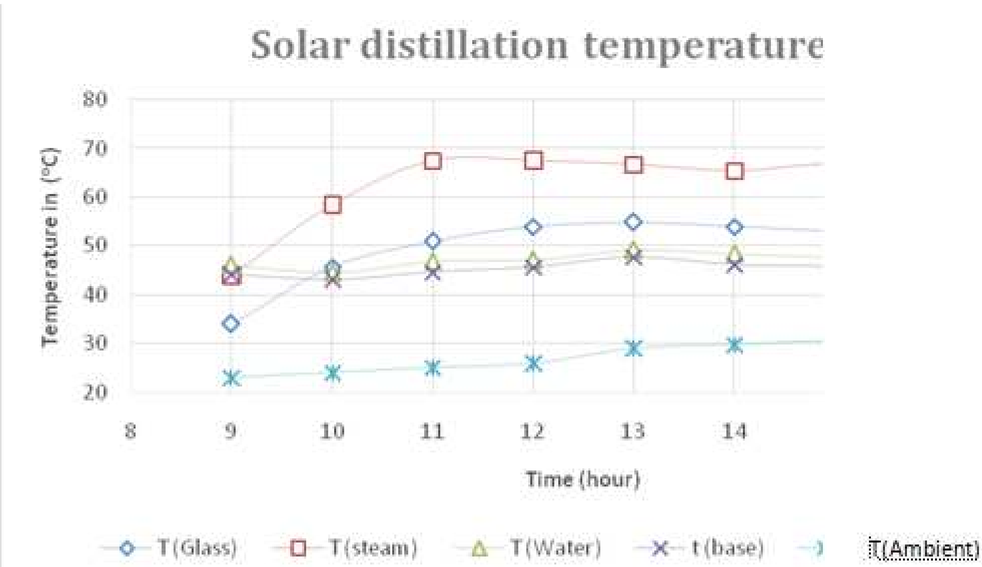

Figure 5: Temperature Variations in the Solar Still.

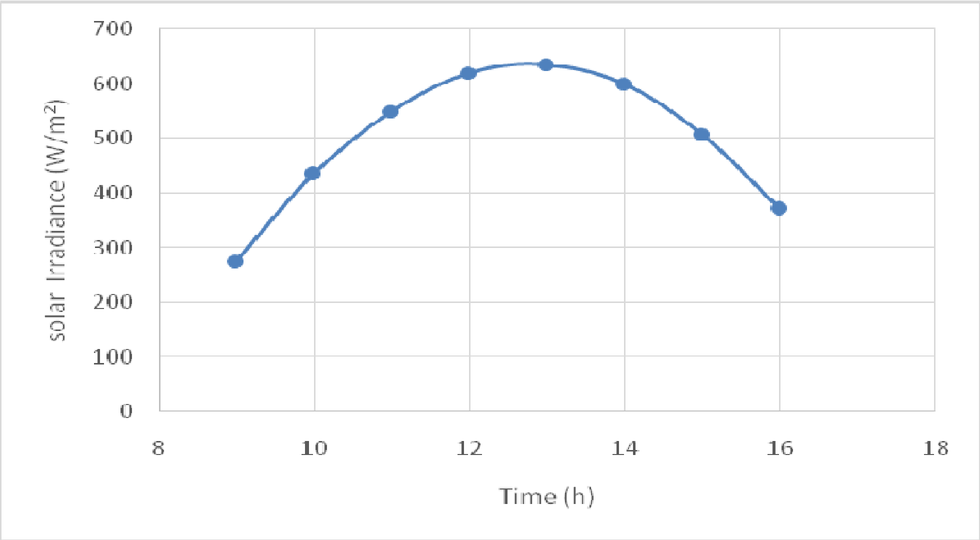

Figure 6: Solar Radiation.

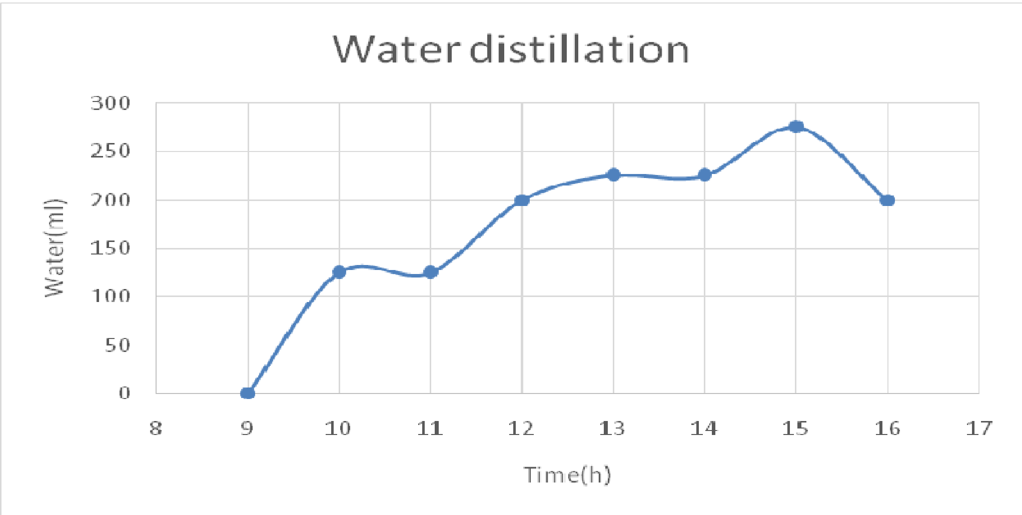

Figure 7: Solar Still Output. Total Water Yield=1375ml.

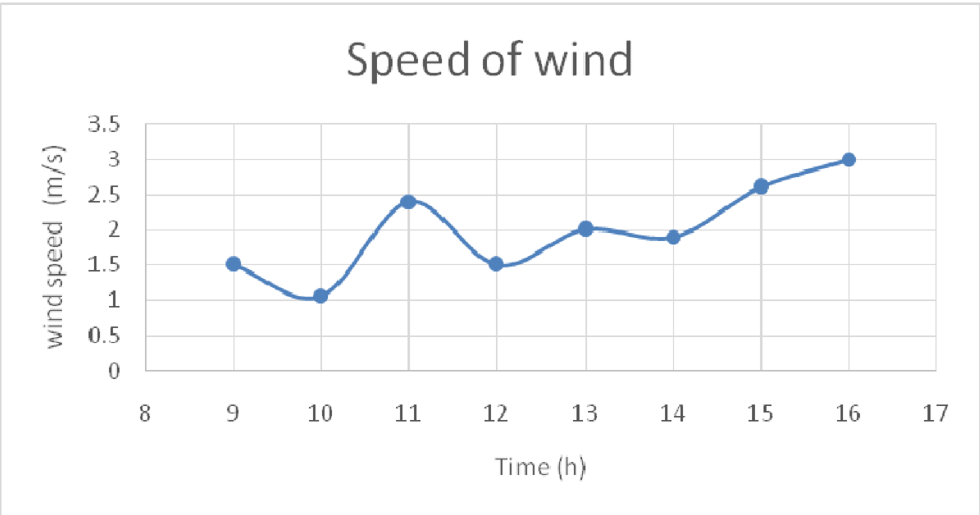

Figure 8: Wind Speed.

It is experimentally evident from figures 5 and 9 that higher basin temperature of water due to the vacuum tube use enhances the productivity, which is consistent with the findings of many previous studies conducted, such as [5,6,7,8,9,10]. The present augmentation technique raised up the temperatures of the water in the basin and the evaporation process, which led to a more distillate output.

Warming up the inlet water of the solar still using a vacuum tube collector has proved to be highly productive. However, the increased temperature differences between water and cover because of wind effect can promote the productivity significantly, which ensures continuous evaporation.

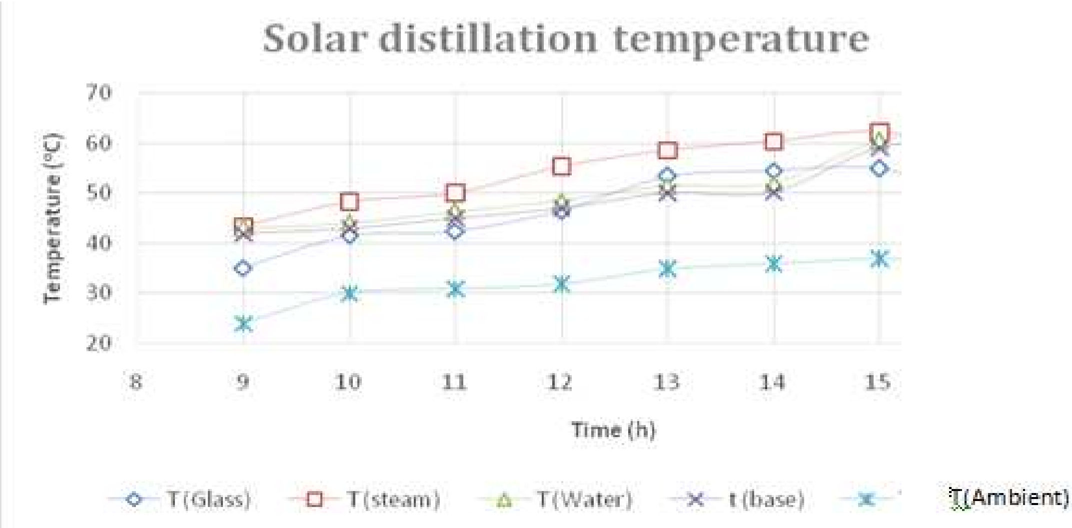

Figure 9: Temperature Variations in the Solar Still.

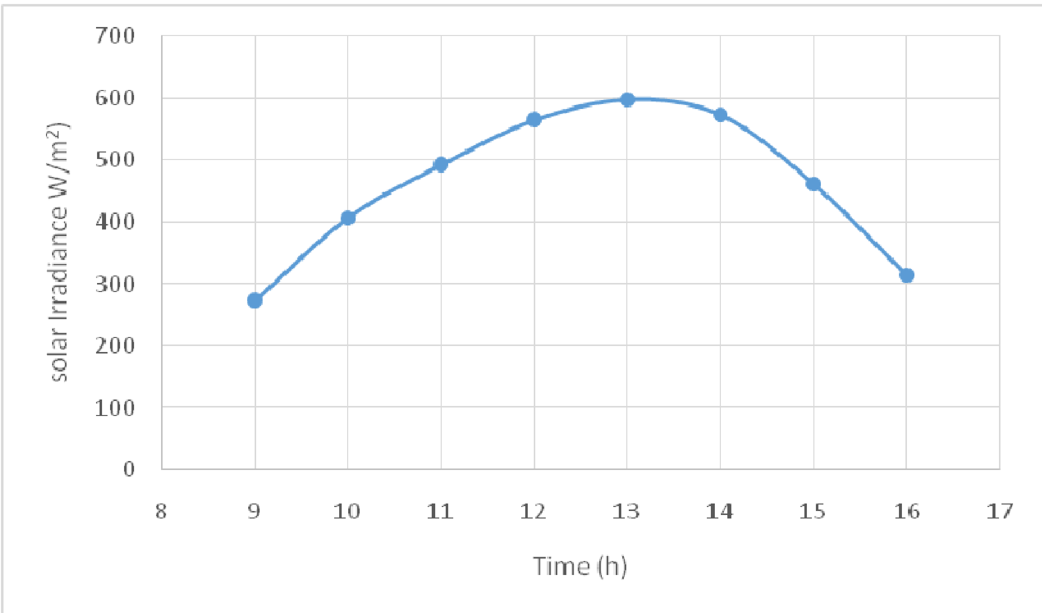

Figure 10: Solar Radiation.

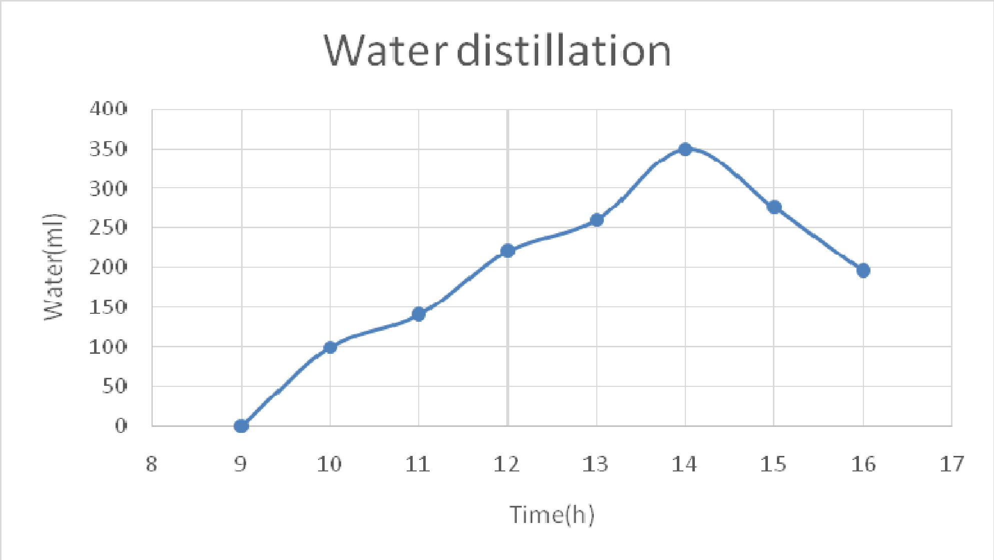

Figure 11: Solar Still Output. Total Water Yield=1540ml.

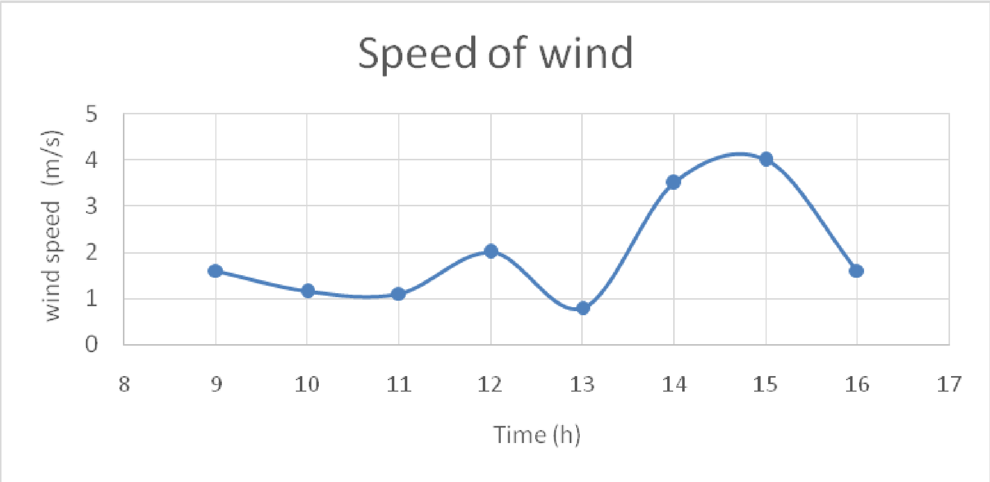

Figure 12: Wind Speed.

The solar stills coupled with solar collectors are appropriate technologies because they do not use electricity to run and purify brackish water from bacteria; also it has easy maintenance and operation.

6. CONCLUSIONS

Solar water distillation is a renewable process and does not need energy source. The water that is produced by the solar still is of a good quality because it is clean from contaminants and has no high minerals. The solar stills productivity can be enhanced using solar vacuum tubes, especially in areas with water problems for producing drinkable water.

From the results, it can be concluded that the ambient temperature and the wind are effective factors in enhancing the stills productivities. Hence, the wind will cool the glass and increase the condensation of steam inside the still. The solar vacuum tube will increase the water inlet temperature entering the still that can raise the heat capacity of the water and speed up the evaporation process.

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